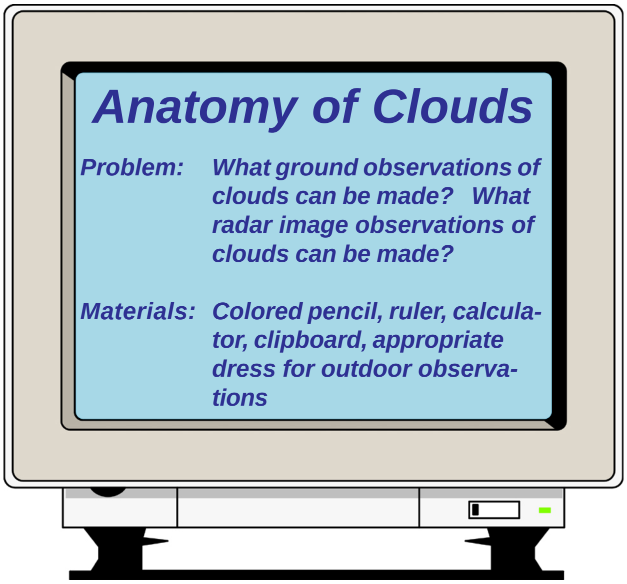


Background

Do you have a halo above your head? Have you seen a rainbow in the sky? Chances are that you have not seen a halo lately...behavior notwithstanding...but you have more likely seen a rainbow. Both rainbows and halos are water-related phenomenon. Water drops create rainbows; ice crystals create halos. Both rainbows and halos display the rainbow-like colors of the electromagnetic spectrum: red, orange, yellow, green, blue, indigo, and violet.

FYI

Halo
A narrow white or colored ring or arc, with a large diameter, that forms around the sun or moon. Halos are seen as light is refracted through ice crystals in cirrus clouds, or when the sky is filled with falling ice crystals.

Rainbow
A colored arc formed by the refraction and reflection of light as it passes through drops of water. A rainbow always appears in the sky opposite the sun.

Besides providing us with an awe-inspiring array of shapes and sizes to observe, clouds play an important role in our everyday lives by helping to regulate our weather and climate. These bundles of densely concentrated, tiny water droplets or ice crystals are floating factories that convert Earth's ample supply of surface water into its relatively scarce and highly mobile supply of precipitation.

All clouds contain water, yet water is not always falling to the ground. Why? There are two reasons: First, most cloud droplets are so small that the movement of air keeps them suspended. Second, even if the small droplets fall, they evaporate before reaching the surface.

Frequently, high level clouds are made of ice crystals, not water droplets, and form when there is moisture at high altitudes colder than freezing. Human activity adds to the formation of these clouds. As water droplets from airplane exhaust spread across the upper atmosphere, they freeze and produce long lines of ice crystal clouds in a narrow trail of condensation called a contrail. Often, high clouds are not visible because lower clouds block our view of them. Semi-transparent clouds, through which blue sky can be seen, are usually composed entirely of ice crystals.

Besides helping to determine our weather, clouds influence our climate. (Climate is a description of weather conditions over time.) Clouds can block, reflect, or absorb energy from the Sun. Ground-based observations as well as balloon-launched observations do not provide enough information to understand the role that clouds play in our atmosphere. Therefore, researchers have developed remote sensors to improve cloud observations. One of these new tools is the millimeter-wave “cloud radar”, a type of Doppler radar.

The cloud radar antenna is a “dish” shape that constantly moves, or scans, in a vertical arc from one horizon to the opposite horizon. While it scans, the radar sends out radio pulses and listens for the returned signal reflected from water droplets and ice crystals.

Cloud radars transmit radio waves in pulses at wavelengths that are about 3 to 8 mm long - shorter than those used to cook food in a microwave oven. Water droplets in the air reflect the pulses. Some of the radio energy returns to the radar where it creates a picture of the cloud and how it is moving.

Unlike the more familiar radars used in weather forecasting, cloud radars allow researchers to see details of the interior structure of clouds in ways that the eye or optical instruments cannot observe.

Procedure

Part A

Using Table 1.1, Cloud Observations, go outside to observe the weather and fill in the information about clouds. Try to make your observations at the same time each day for at least one week. Use the information tables at the bottom of your data table to guide your observations. For cloud height, you may be lucky enough to have a local geographic feature to help guide your observations. Otherwise, use “cloud groups” to help identify height. Note that the darker the cloud, the more water it probably contains. Look for patterns and relationships among the data that you collect.

For example, you can learn about the winds aloft by watching clouds move. Often, if there are clouds present at different heights, they may be moving in different directions as they drift with the winds at those heights.

Day And Time	Cloud Cover (Symbol/Fraction)		Cloud Groups (Sketch/Name)		Height (High) (Middle) (Low)	Shades of Gray Light 0-5 Dark Color	From Which Direction Clouds are Moving	Current Weather Partly Cloudy, Clear, Cloudy, Precip

Cloud Cover

Symbol	Fraction
	* No Clouds * 1/10 or Less * 2/10 to 3/10 * 4/10 * 5/10 * 6/10 * 7/10 to 8/10 * 9/10 Overcast with Openings * 10/10 Complete Overcast * Sky Obscured

Cloud Groups

Sketch	Names
	* High Clouds - Cirrus - Cirrocumulus - Cirrostratus - Contrails (Above 5,000 meters)
	* Middle Clouds - Altocumulus - Altostratus (2,000 - 5,000 meters)
	* Low Clouds - Stratus - Stratocumulus - Nimbostratus - Fog (Cloud at Ground Level) (Ground - 2,000 meters)

Sketch	Names
	* Cumulus Clouds - Small Cumulus - Swelling Cumulus (500 - 18,000 meters)
	* Mixed Skies

Table 1.1. Cloud Observations

SAM II 1-3

Note: Ideally, data should be collected twice daily. You are more likely to observe trends in the space of a few hours than over a 24-hour period. Therefore, try to arrange with classmates to share data if you cannot make your own observations.

Questions

Part A

1. What fraction of the sky was covered most often?

2. What cloud group did you observe most often?

3. When skies were cloudy, were there high, middle or low clouds most often?

4. From what direction did clouds come most often?

5. What relationship(s) did you notice among the observations that you made? (For example: Low clouds are usually darker gray).

6. How can you tell whether clouds might contain water droplets or ice crystals?

7. Design a weather related investigation. Use Table 1.2.

Investigation

Use the following format to design your own investigation. Since you probably need more space to write a good proposal, use the space below for a rough draft. Make notes and organize your ideas.

Title:

Problem (Question) or Purpose:

Hypothesis (Educated Guess):

Materials:

Procedure:

Data (Tables and Graphs):

(Fill in "Data," "Discussion," and "Conclusion" after you collect data.)

Discussion (Explain your Data):

Conclusion (Answer the Problem, Question, or Purpose):

Table 1.2. Your Own Weather Related Investigation

Procedure

Part B

To learn more about clouds, researchers need to take a closer look than we can get from ground observations. Therefore, they use a type of Doppler radar to "see" the tiny water droplets and ice crystals that form clouds, and to better understand how clouds form and flow.

One type of cloud that researchers study is a "breaking wave" cloud. These unique looking clouds form in air layers of different densities.

As each wave appears to stretch and curl over, it mixes the different layers of air. Mixing the layers affects the growth of water droplets or ice crystals in the cloud, and therefore, cloud formation and weather.

Figure 1.1, the following photograph, shows a breaking wave cloud. Notice that it looks much like breaking waves on the ocean.

Figure 1.1. A Breaking-Wave Cloud

Photo by Brooks Martner
NOAA/NOAA Research - ETL
Boulder, Colorado

Sample cloud radar images of reflectivity and velocity are given in Figure 1.2. The cloud radar image shown in Figure 1.3, Cloud Radar Worksheet is also a breaking wave, although not the same cloud.

The reflectivity image on the top of both figures shows the moisture content of the cloud; the velocity image on the bottom shows cloud motion as recorded by Doppler radar.

The data for this activity were collected from the National Oceanic and Atmospheric Administration (NOAA), NOAA Research, Environmental Technology Laboratory (ETL), in Boulder, Colorado.

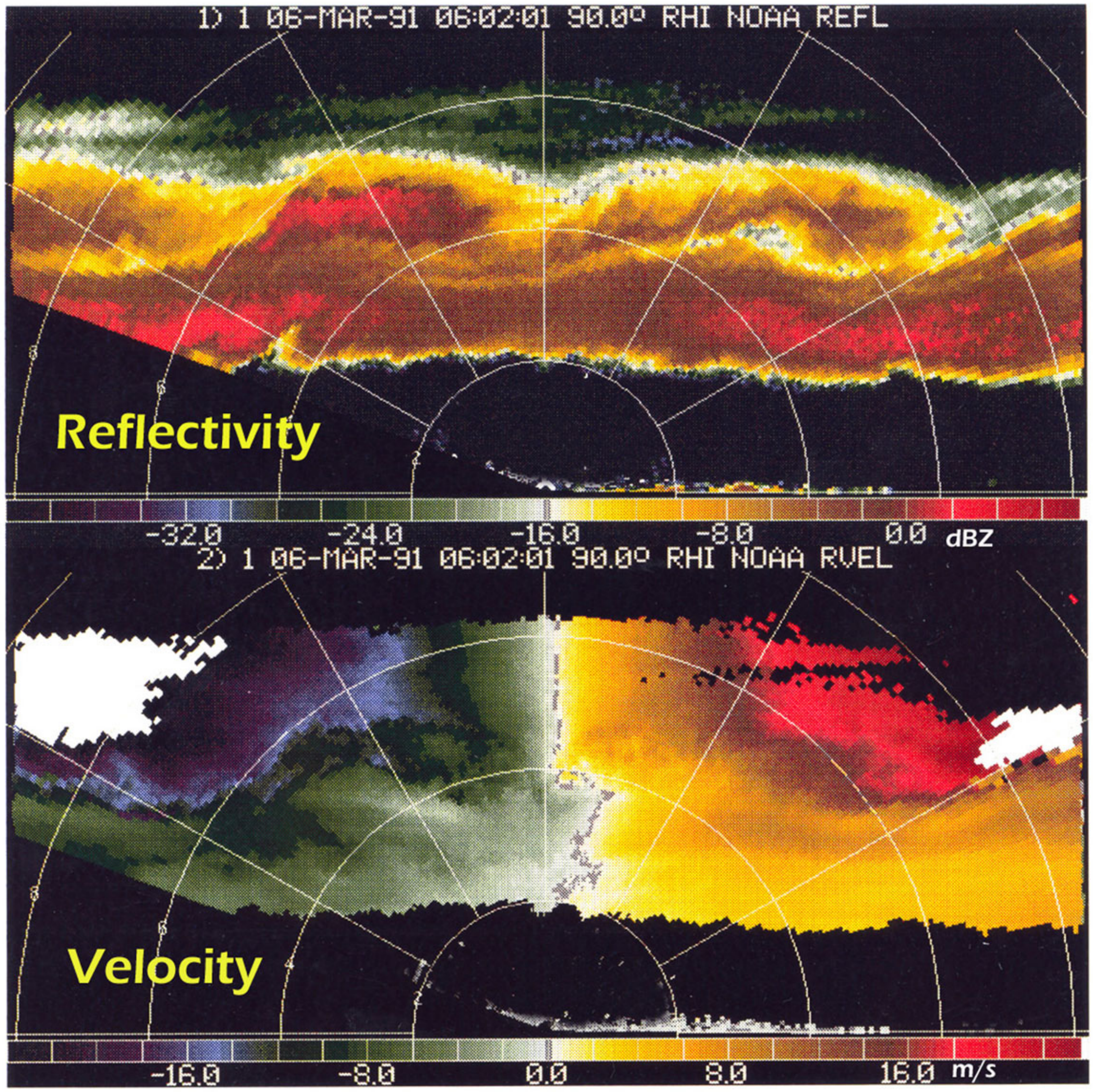


Figure 1.2. Cloud Radar Image - Reflectivity and Velocity

Reflectivity Radar Image

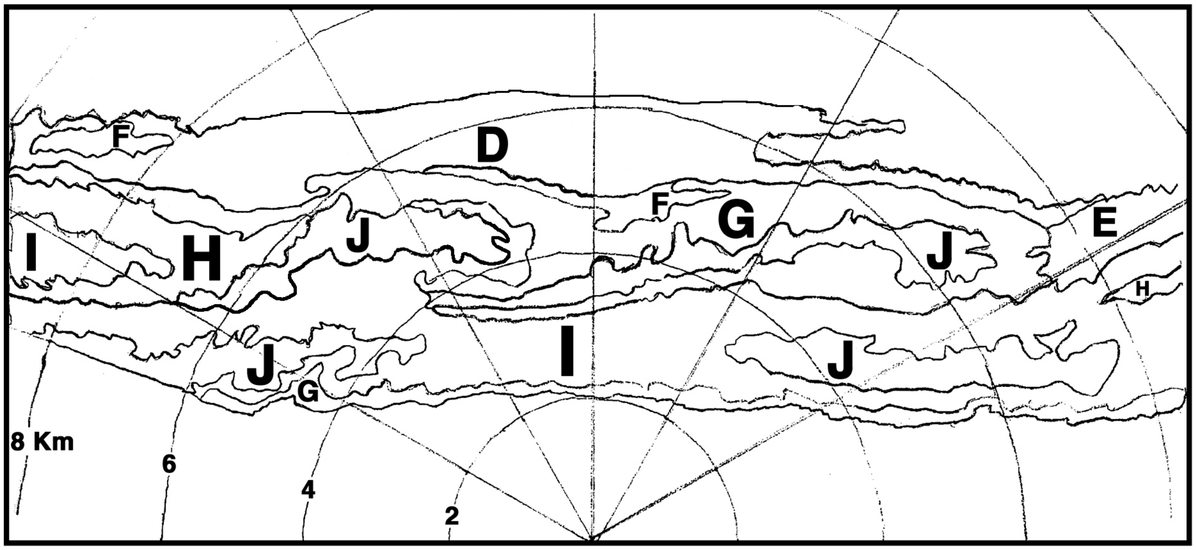
The strength or intensity of a cloud radar image depends upon the amount of moisture in the cloud, either water or ice. Clouds with larger, and more, water or ice particles have a greater radar intensity; this is called reflectivity. Researchers use the colors of the spectrum to indicate reflectivity. The color red (warmer color) indicates high reflectivity and the color blue-violet (cooler color) indicates low reflectivity with gradations between.

Velocity Radar Image

Meteorologists, as well as astronomers and other physical scientists, use the color blue or violet to indicate movement toward radar and the color red to indicate movement away from radar. The image on the bottom of the Cloud Radar Worksheet shows the pattern of Doppler velocities that cover a radius of approximately 8 kilometers around the radar site.

Reflectivity Radar Image

Zenith

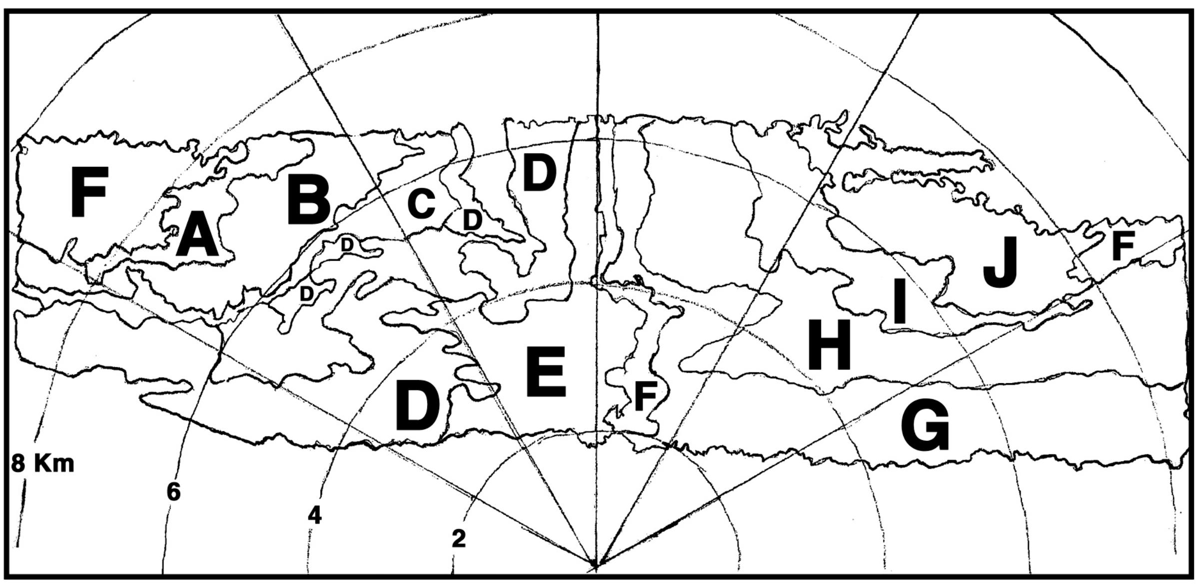


A	B	C	D	E	F	G	H	I	J
-38 to -40	-34 to -37	-30 to -33	-20 to -29	-17 to -19	-16	-11 to -15	-6 to -10	0 to -5	>0

(dBz) Decibels Decibels (dBz)

Velocity Radar Image

Zenith



A	B	C	D	E	F	G	H	I	J
-21 to -24	-17 to -20	-15 to -16	-5 to -14	-1 to -4	0	1 to 4	5 to 10	11 to 16	17 to 20

(m/s) - (Meters per Second) (Meters per Second) - (m/s)
(Negative numbers indicate motion toward the radar, while positive numbers indicate motion away from the radar.)

Figure 1.3. Cloud Radar Worksheet

Now using the Cloud Radar Worksheet...

1. Color the scale at the bottom of the Cloud Radar Worksheet according to the color key at the right.

2. Using your completed scale as a key, color both the reflectivity and the velocity radar images.

Color Key

Color key for both the reflectivity and velocity radar images on the Cloud Radar Worksheet (Figure 1.3).

Section A = Dark Purple or Violet
Section B = Light Purple
Section C = Light Blue
Section D = Dark Green
Section E = Light Green
Section F = No Color or White
Section G = Yellow
Section H = Orange
Section I = Brown - Red
Section J = Red

For example, areas marked with a "G" should be colored yellow. Ignore the concentric circles and radius lines of the radar screen. It is OK if your boundaries between colors blend together because that is how a real radar screen would look. The velocities of the clouds do not suddenly change in one spot, but change more gradually over a distance.

3. Place an "X" on the Doppler transmitter station for both the reflectivity and velocity radar images.

Questions

Part B

(Use Figure 1.3 to answer all the following questions)

Reflectivity Radar Image

1. What is the diameter of the outer range ring (only parts are visible) for the radar screen in kilometers?

____

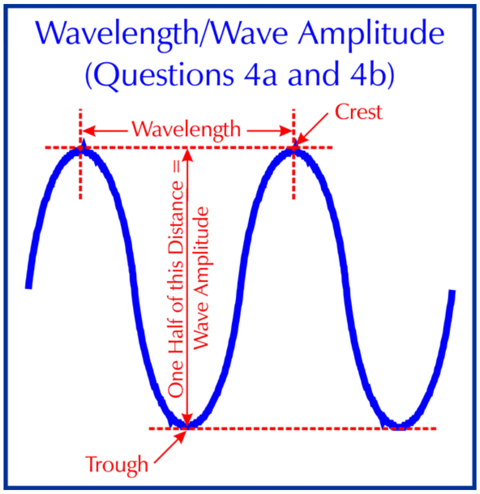
2. What is the diameter of the inner radar range ring in kilometers?

____

3. How many clouds can you identify?

____

4. Use the distances written on the range rings and a ruler to estimate the following distances.



a. Wave length (distance from the crest of one wave to the crest of the next wave)

b. Wave amplitude (one half the vertical distance from the trough to the crest) of the wave in the center

c. Cloud-base (distance from the Earth's surface to the bottom of the cloud)

d. Cloud-top height (distance from Earth's surface to the top of the cloud)

5. What is the vertical thickness of the clouds?

6. Describe the internal motion of the cloud.

What does this tell us about our atmosphere where this cloud is located? (Hint: Colors indicate speed for different parts of the clouds.)

Velocity Radar Image

1. What two colors represent the fastest air velocities, and what are their speeds in meters per second?

2. How many degrees represent the distance from the ground to the zenith?

3. At about twenty degrees above the surface on the east side of the radar image, what is the greatest cloud speed?

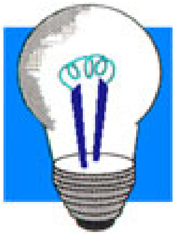
4. At about thirty degrees above the surface on the west side of the radar image, what is the lowest cloud speed?

5. If you are flying in a plane from west to east, describe how the wind would influence the plane.

6. Change the cloud velocity from 15m/s to m.p.h. Use the unit analysis technique set up below.

$$\_\_\_\_\_\ \text{m/s} \times \frac{1\ \text{km}}{1000\ \text{m}} \times \frac{0.6\ \text{mi}}{1\ \text{km}} \times \frac{60\ \text{s}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{hr}} = \_\_\_\_\_\ \text{mi/hr}$$

SAM II 1-11



Conclusion

Review the problem stated on the first page and write a detailed conclusion.